

SOME PARTICULARS OF THE LANDING AIDS DLS AND SETAC

K. D. Eckert and G. Peuker

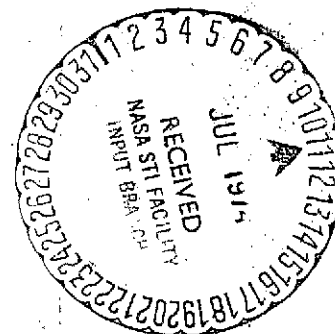
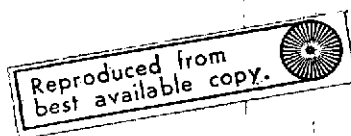
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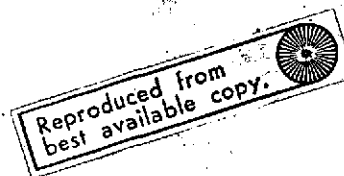
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16. Abstract The article describes the participation of the German firm SEL in the development of the SETAC landing aid system (sector-TA CAN) which consists of a complex of ground stations and on-board apparatus. One of the distinctive features of SETAC is a 15 kHz circular beacon SROB which allows azimuth to be measured over 360°.			
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SEL Stuttgart

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1. Introduction

For some time, various international and national organizations (for example, RTCA-SC 117, the ICAO and the NIAG) have been making efforts to choose a successor system for the ILS landing procedures that are now in use. /1*

The bases for the desire for an ILS successor for the years of the later 80's are very numerous. Here only a few selected ones will be cited:

- The problems of multi-path broadcasting, especially for the glide path, which, for example, in ILS, frequently requires painstaking and costly preparations of the field.
- The increasing demands on the capacity of the airports, which cannot be met by the traditional ILS, or can only be met with great difficulties.
- The relatively large mechanical measurements of the ILS on the technical side, and the rapid further development of flight equipment relative to type, size, and speed on the operational side.
- The demand for common use of the same system for military and civilian purposes, which can only be met by a new, considerably more flexible system, because of the information supplied by the ILS and because of the volume of information covered by it.

The list of these arguments could be considerably enlarged still, because, in addition, the technical and technological possibilities since the inception of ILS have further developed to a considerable extent, which is especially true for the

*Numbers in the margin indicate pagination in the foreign text.

microwave region, but also, for example, for the digital technique. It is therefore completely understandable that we are striving not only to meet the problems presented by the ILS as well as /2 expanded operational demands with a new system, but to arrive through this process at a new system with a series of desirable new properties.

However, there exists here a great danger. Many times operational advances are first developed by technology, and then represented as being unconditionally necessary.

Whatever has unsatisfactory overall properties in many places or for many users, can easily lead to a technical solution. Examples of this are the demands of coverage, where often a hemispherical coverage in azimuth and elevation (360° azimuth and 90° elevation) is required, in the introduction of landing aids in the ATC region, and partly also in the demands of accuracy, e.g., we may think of the question of taxi guidance. Naturally, flexibility must be a prime consideration in the choice, that is, the ability of a system to be able to meet possible demands of the future which cannot yet be completely defined. This is very likely one of the roots for the complexity of the problem in the choice of a new system. Another basis can well be pointed out, in that the demands on a new system can be substantiated differently in individual nations. And, naturally, not last, economic interests play a not insignificant role.

In view of this state of affairs, the Firm SEL, as the leading German firm in the field of radio landing aids, resolved to participate in two proposals. The development of the landing aid SETAC for the military, that is BMVg/BWB, is already well /3 advanced. Thereby an urgent need of the Federal Republic, resulting from its special tactical-geographical position, will

be covered. The introduction of the SETAC system should follow as rapidly as possible, and the system should remain in service at least for the next 20 to 30 years.

The conception phase for the landing aid DLS is largely concluded.

In the scope of the NIAG-SG1 (prefeasibility study for Advanced Approach Landing Systems), both systems were presented as proposals for future military landing systems. Also in the scope of the ICAO evaluation, the Firm SEL has proposed the pursuance of both systems to the German government.

For special reasons, at first only the DLS was presented to the ICAO. The development of this system will likewise have been started in the next few weeks, and indeed with the participation of the Firm Siemens AG.

At first glance, very little chance of success is seen for SETAC based on TACAN, since TACAN is not designed for the civil area of today (although the DME today is a strong component of civil aviation). Until the ICAO decision around 1976, the SETAC system will be tested by comprehensive flight measurements, and would have, on the basis of good results, possibly a good chance to be noticed.

In this report, several interesting particularities of this system will be stressed.

2. Short Description of SETAC

In spite of a number of publications concerned with the subject of SETAC, I might here place a short procedure description before the discussion of some system particularities. As the

name already says, which, by the way, arose from a shortening of the word sector-TACAN, this landing aid rests largely on the international mid-course navigation system TACAN, which is used primarily in military aviation, and forms therefore, a so-called 'air-derived system.' It consists of two ground stations and one additional on-board apparatus with a TACAN on-board apparatus. The use of TACAN frequencies and a TACAN signal format expanded with the help of time-multiplex procedures, permits the use of the TACAN on-board apparatus, generally used for mid-course navigation, also to be used for the approach and landing phases.

Fig. 1 indicates the information stream that is exchanged between the different system components.

We begin with the SETAC-A Ground station, where A will symbolize the concept of azimuth. It forms an independent mobile partial system within the SETAC system, and provides the following information:

1. The SROB information (short range omnidirectional beacon) is a short-path signal near the azimuth (range about 30 nm), which makes it possible for the aircraft to enter accurately into the approach sector, characterizes the chief sector of the sector angle information, and makes possible an overshoot guidance. The SROB signal has the character of a TACAN coarse signal measurement, and is produced by a VOR-S-like fully electronic antenna.
2. The sector angle information is a precision azimuth signal, /5 that also exhibits complete TACAN character, and within a limited sector of preferably $\pm 18^\circ$, symmetric on the ground approach line, takes over the precise lateral guidance during approach and landing. Pulses synchronized with the SROB signals are radiated as carrier and sideband signals in

such a way from a special antenna arrangement with a basic length of some 15λ , that, in this sector, there occurs complete TACAN information. (See Fig. 2.) The compression of the TACAN information obtained by this arrangement compared with the customary TACAN leads on the one hand to the desired enhancement of the solution and precision, but on the other hand has, as a result, the occurrence of sectors with ambiguous interpretations, that are removed with the help of the SROB information.

3. The precision distance information (PDME) allows the exact measurement (error $\approx \pm 20$ m) of the diagonal distance aircraft-SETAC A-ground station. Since the SROB antenna is used for the distance measurement at the ground station (Transponder), a PDME provision of the volume of coverage is secured, in which also the SROB information is available.
4. As the fourth and final group of information, the SETAC-A ground station allows the transmission of digital data from the ground station to the aircraft at a rate of about 2.15 kBit/sec as well as the broadcasting of the ground station identification signal.

The SETAC-E ground station is the second ground component of the system. It supplies, as its name already says, the angle of elevation. The signals broadcast from its antenna have the same carrier frequency as the signals sent out from the SETAC-A ground station, and are synchronized with these by a time-multiplex /6 scheme, so that the principal statistical character of all broadcast SETAC signals remains constantly unchanged. The E station is likewise mobile, and, as a rule, is erected about 100 m laterally displaced from the ideal touchdown point. (See Fig. 3.)

The third SETAC system component is the on-board apparatus,

more precisely, the SETAC on-board apparatus which is supplementary to a TACAN on-board apparatus. While the TACAN apparatus takes over all HF functions, the channel selection function, ZF strengthening, etc., as well as the evaluation of the SROB and PDME information, the additional information on sector angle, elevation, and data are evaluated in the supplementary on-board apparatus. This supplementary apparatus therefore contains no HF elements.

3. Particularities of SETAC

After this survey of the SETAC system, which was necessarily defective and incomplete because of the shortness of the time available for its completion, I might now turn my attention to some particular points about this landing system.

One of these peculiarities is the 15-kHz circular beacon SROB, which allows the measurement of the azimuth with 360° coverage, as well as the precision distance measurement to the terminal area.

The SROB information is radiated from a circular broadcasting special antenna that electrically produces a vertically polarized cardioid diagram with 15 Hz rotational frequency. It forms a 7 constructive unit with the SETAC-A ground station (see Fig. 4). The transmitter stage is part of the common apparatus. On account of the use of the same reference signal for sector angle information and SROB, the additional cost of the apparatus attributable to SROB itself is extraordinarily small.

As already mentioned, the SROB antenna furnishes a vertically polarized radio field in the space around the installation, which exhibits a cardioid-shaped directional characteristic in the horizontal plane, which rotates with a frequency of 15 Hz.

It works with fixed radiating elements and electronic turning of the directional characteristic, whereby the total diagram is constituted from different components. (See Fig. 5.)

Two radiating systems arranged orthogonally to one another produce two figure-eight diagrams displaced by 90° in space. By feeding this radiating system from a goniometer with sine/cosine shaped modulated HF energy, there is obtained a rotating figure-eight diagram. By superimposing a non-directional radiation (round diagram), one finally obtains the rotating cardioid-shaped directional characteristic.

The fed elements of the antenna are four monopoles, which are arranged on a circle (respectively displaced at 90°). Excitation in opposite phase of two monopoles parallel to one another produces, in turn, a figure-eight diagram; feeding all four monopoles in the same phase affords a circular diagram.

To form the vertical diagram of the antenna, the monopoles are installed in a funnel-shaped metallic construction (body of the antenna). Fig. 6 shows the vertical diagram provided. Extensive ground and flight studies have been carried out in the last six months with the system components SROB. Their results confirmed almost completely the theoretical prediction with regard to coverage, range, and precision. In sum, with respect to the accuracy obtained, it can be said that the SROB results that actually must correspond to a TACAN gross measurement gave an average error of $\pm 2-3^\circ$. /8

The other peculiarity of the SETAC system, which will be mentioned here, is the process of the virtual diagram used for the angle of elevation measurement. The measurement of the angle of elevation is undertaken with the help of the sub-system SETAC-E, which has at its disposal its own transmitter as well as its own transmitting antenna installation.

A sine curve follows from a vertical arrangement of the transmitting antennae of the ground station and measurement of the phase differences of the information changes at variable elevation. That means that for small angles of elevation, the information gradient reaches a maximum value. This is essentially the basis for the use of a vertical line for measurement of elevation according to the SETAC-E procedure.

The problem to be solved in the measurement of the angle of elevation consists in so providing elevation information in a region between 1° and at least 60° , that on board the aircraft in landing approach, the desired flight path can be freely chosen. The determination of the respective angle of elevation is undertaken by a measurement of path difference, which a signal on the path to the receiver undergoes, if it picks out the radiation from the various single rays that are arranged lengthwise as a perpendicular vertical to the earth. The greatest interference effect occurring in the measurement of the elevation is brought about by the reflection of the emitted signal from the ground (see Fig. 7). The amplitude and the phase of these ground reflections in practice cannot be predicted, and therefore must be eliminated from the received signal. Therefore, not only the signal broadcast from the ground antenna in a direct direction is received at the on-board receiver, but also a further component reflected from the ground. The superposition of both signal components in the radio field results in a falsified resultant signal with respect to phase and amplitude, and therewith feigns a false signal from the sending antenna on the ground to the receiving antenna on board.

Especially at small angles of elevation, which are of special importance for CTOL aircraft, and all fast-approaching high-performance aircraft are such CTOL aircraft, the elevation angle signal--radiated from a vertically standing antenna and vertically

polarized--is influenced strongly by reflections from the ground. The different procedures found in use today deal with this phenomenon in different ways. Thus, for example, the conventional ILS requires an antenna outlook that must be, as far as possible, planar, homogeneous, and free of obstacles, since the ILS guidance information comes about with deliberate withdrawal of the signal component reflected from the ground. Other procedures try to minimize the disturbing influence of the ground by corresponding formation of its transmitting antenna group diagram. Examples of this are the so-called 'scanned beam' procedures, in which very narrow radiation beams occur by use of relatively very large variable antenna apertures, which illuminate the ground only very little during the mechanical variation processes, for example. The SETAC processes constitute a third path. Essentially isotropic beams are used at the ground antenna, which illuminate the ground just as strongly as the on-board antenna. The separation of useful and interfering signals then becomes one of on-board evaluation with the help of mathematical processes. /10

One such mathematical process also forms the basis for the procedures of the virtual diagram. If one feeds a linear arrangement of n isotropic radiating elements into the open simultaneously with signals of the same frequency, amplitude, and phase, then there results a definite group diagram that depends on the distance of the individual radiating elements and on the length of the array for its outlook. The form of this group diagram is changed by changing the radiation input according to amplitude and phase, with retention of the geometric configuration. In this way, almost any diagram configuration can be obtained. The central thought of the virtual diagram is now the following: since such a broadcast system, consisting of transmitter, antenna feed system, antenna array, broadcast medium, receiving antenna, receiver, and evaluation, is a dual one, certain actions on the sending side can be shifted to the receiving side, without

altering anything in the overall broadcasting system or in the herewith produceable results. Therefore, if one sends from the transmitting antenna array equal signals, one after another, and measures at the point of reception the amplitude and phase of the individual measurements, stores these measured values on board, together with the antenna numbers belonging to them, then the measurement of the incoming signal can be undertaken according to amplitude and phase in the on-board apparatus instead of at the ground station. Thus, in the on-board calculator, in practice every possible group diagram can be reconstructed, and indeed so that it is optimally adapted for a momentary observational use. Among other things, such diagrams allow one to irradiate the earth not at all, or only very little, and thereby to complete a measurement of the angle of elevation which is free from interfering signals to a very high degree, even though these diagrams are not real, but are, therefore, called virtual diagrams. /11

It must again be pointed out that in this way no restrictions on the area of coverage arise in the diagram formation, since the radiating elements of the transmitting antenna array are set up according to the prerequisites for isotropic spherical radiators.

Disregarding similar uses in side-looking radar (SLRA), this idea is new in the field of modern location technology, and its effects and the possibilities of its use can today be not at all completely disregarded or overlooked. One certainly cannot go wrong today with the statement that this idea will yet have many important results for the most varied fields of radio location.

The following precautions must be met in order to be able to determine the angle of elevation measurements of the approaching aircraft according to the method of 'antenna aperture synthesis':

- It must be possible to measure on board the relative phases and relative amplitudes of the signals from each radiating element of the SETAC-E antenna.
- It must be possible to classify all measured values on board /12 according to the corresponding antenna number and to store them individually.
- The on-board evaluation must be done by a calculator which undertakes the further working-up of the stored data.
- Every radiating element of the SETAC-E ground antenna must exhibit as much as possible the same radiation diagram in amplitude and phase.
- Each element of the ground antenna radiating system must radiate the same signal in frequency, amplitude, and phase.
- The system must be able to be synchronized for the cycle and the radiator, that is, on board, the beginning and end of each cycle as well as the number of the upright transmitting antenna must be known.

The mathematical processes to be carried out from the evaluation calculations consist essentially of the multiple addition of vectors, as well as the determination of the phase angles between the resulting vectors, from which, then, in its turn, the elevation itself is determined by forming an arcsin function.

By the use of these procedures, the angle of elevation is determined under the following conditions:

1. Through the blanking out of the ground with the help of the virtual diagram, the antenna outlook information plays almost no further role at all.

2. The height of the SETAC-E ground antenna above the ground is practically completely eliminated from the results of these elevation angle measurements.

113 3. The amplitude as well as the phase of the measurement 1/13 data are used, so that, on the one hand, angles of elevation even below 1° can supply accurate interference-free measurements, and, on the other hand, even angles of elevation of more than 70° can be determined with errors of measurement of less than $\pm 0.1^\circ$ (Fig. 8).

Naturally, the true extensive and complex subject of the synthesis of virtual diagrams can be described here only by intimation, which by the way also applies to the DLS now to be discussed.

4. Short Description of DLS

Before we go more deeply into some particulars, the DLS 1/14 should be briefly described. The system is based on the DME in the L-Band, from which the name DME-based Landing System arose. The distance is measured in a well-known manner, by the procedures (PDME) that have been considerably improved by SEL in the area of the MITAC and SETAC work: questioning from on board, transponder on the ground, reply after exactly 50 μ s. The query sent from on board is not now received on the ground with a simple round antenna, but with special groups of antenna circles. A horizontal circular group allows the determination of the azimuthal direction of incidence (ω), a vertically arranged circular group allows the measurement of the angle of incidence in the elevation (ϕ). The determination of both angle values happens so quickly in this way, that with the DME reply being transmitted after 50 μ s, this value can be transmitted to the on-board apparatus in coded form. For this, only a small additional expense is necessary to the

already-present DME apparatus, to decode the angle modulated with the particular reply discovered by the search system, and to give it out again for indicator or directional control purposes. (See Fig. 9, Signal stream in DLS.)

We have here, therefore, a system in which the distance is measured on board, and both angles are measured on the ground (mixture of air- and ground-derived coordinates).

5. Particulars of DLS

In Table I, a whole series of special properties of the Landing Aid DLS is itemized. The short time of performance naturally does not suffice to go into everything. Therefore, the following selected points will be described somewhat more closely. /15

One of the major principles in the conception of DLS was to obtain an overall solution at low expense. Allied with this is an important, generally unrecognized, basic rule in the further development of such important navigation systems, namely, to proceed in an evolutionary way, and not in a revolutionary way. In DLS, to a large extent, tested techniques were used: L-Band technology, tested PDME, basically tested sounding-techniques, well-known on-board antenna diagrams.

On different bases, but also to obtain high cost efficiency, a so-called ground-derived system was chosen for the angle measurements. The on-board apparatus must then easily decode the angle values contained in coded form in the reply. No new on-board apparatus, but only a modification (DLS supplement) is made necessary by the exclusion in the ICAO-DME. The expense for this addition can lie in the size range of 20% of the DME apparatus. It is conceivable that future modern DME apparatus are already manufactured and sold with integrated portions of DLS. In that

connection, it is possible to use the L-Band antenna presently on board. This small on-board expenditure must be fairly unrivaled.

The choice of a ground-derived system yields, as a further important advantage, a flexibility that means a high future security. This aspect cannot be valued highly enough if one observes how the operational demands are still discussed.

Figs. 11 and 12 show examples for the possibilities of adapting the ground stations to different demands. In these cases, the on-board apparatus remains unchanged and simple.

The equal wave operation possible in DLS reduces the channel allocation problem. Stations on the same HF channel, for example, can be set up directly next to one another without the reciprocal disturbance of information taking place. Naturally, among other things, a reciprocal time loss will be produced, that is, the capacity of each station can become reduced. This influence depends, in particular, very strongly on different parameters of the statistical DME, and, naturally, on the separation of the two stations. The equal wave operation is achieved because the inquiry from on board is additionally coded, for example, by carrier phase modulation in both DME impulses, possibly also pulse width modulation. For example, one can easily accommodate five bits, that is to say, produce 32 directions. If 10 HF channels are available for exclusive use for DLS, apparently 320 channels can be assigned. The channel selection on board would not differ from a previous HF channel installation.

One of the most interesting particulars of DLS is the signal handling method for angle measurement which is planned to be of a new kind. In the suggested antenna array for the angle determination, all of the single antennae receive simultaneously (about 30 with a diameter of 5λ). This is necessary since only one DME

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impulse (inquiry) of about 2.5 μ s duration is available for taking bearings. The phase and the amplitude from each antenna are measured (both with respect to an average antenna). From this, the determination of the angle of incidence would be possible from the individual phase values (digital measurement--Fourier analysis through digital partial evaluation). However, these values are subject to error from the influence of reflections. The simultaneous measurement of the amplitude also, that is, the complete 'extraction' of the information contained in the electromagnetic field, permits the reduction of these errors now through a corresponding working-up in a very rapid digital analytical portion (reply possible after 50 μ s!). Such methods are especially simple, if only one dominating reflector is in effect. However, this is true in practice only in rare cases. (For example, measurement of elevation).

Therefore, refined methods must be sought. The Firm SEL is undertaking at this time various such methods with the help of reflection models on a digital computer (simulations). The methods are practically identical for the horizontal and vertical arrays, that is, for azimuth and elevation.

It is calculated thereby that the required precision will be obtained with a basis of 5 λ (array diameter therefore about 1.50 m). (See Fig. 13.)

6. Outlook

The Firm SEL is participating in a worldwide activity for the successor of the ILS with two systems, which were touched upon lightly in this presentation. We believe therewith that a useful international contribution has been made. If also private interests were decisive in this endeavor, one should not overlook the fact that a share in this complex technical, commercial, and

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partly even political game, calls forth an entirely appropriate portion of idealism.

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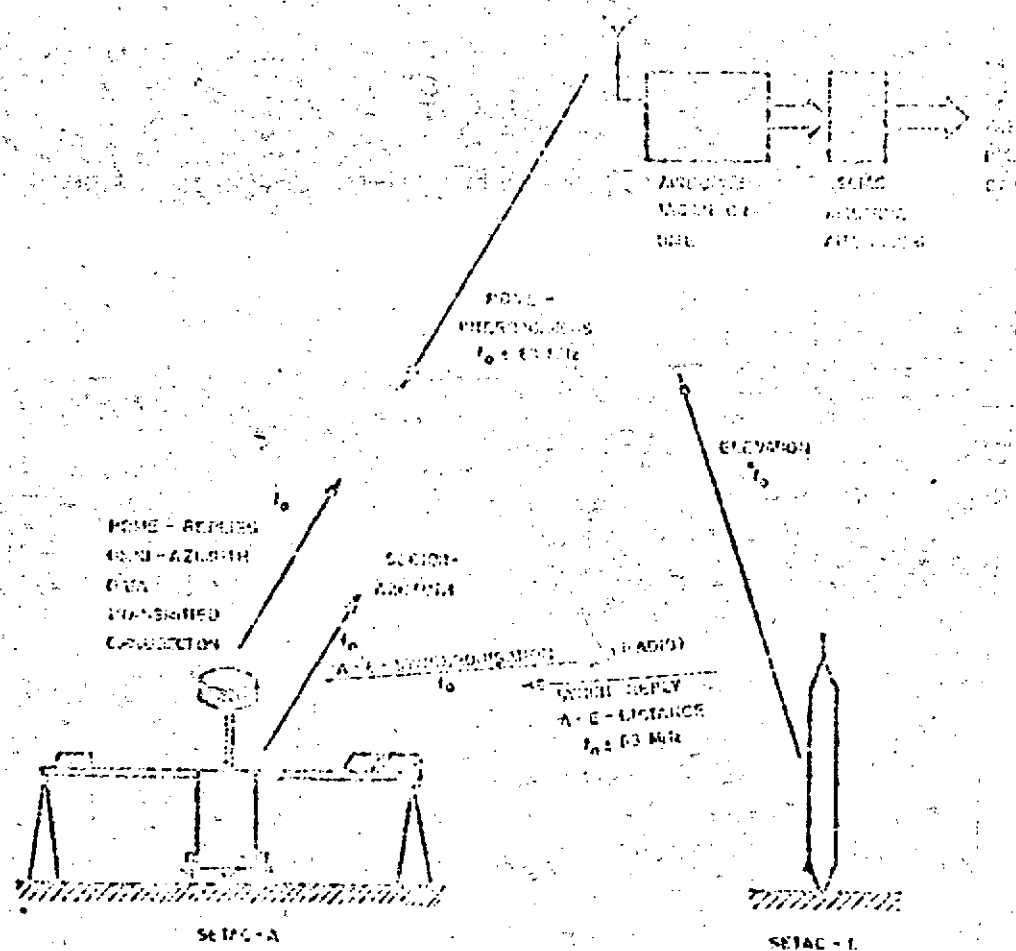
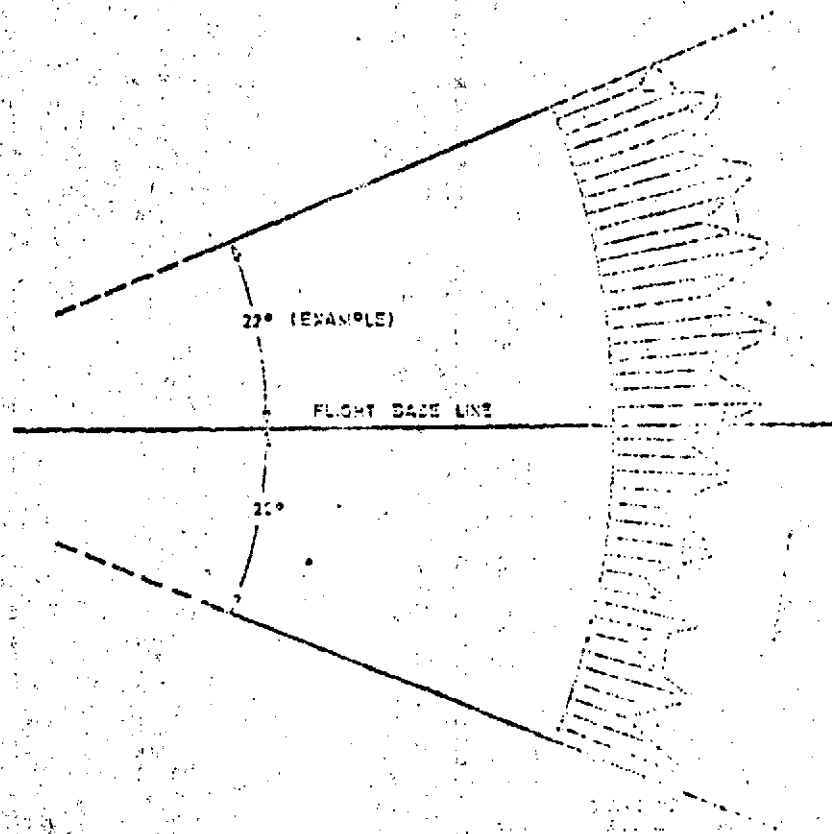
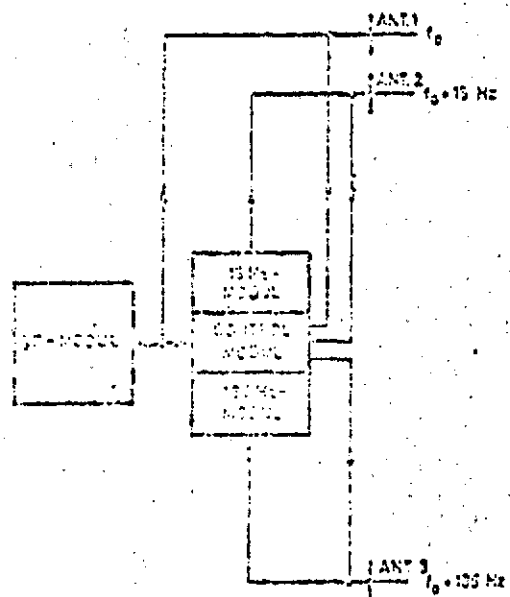


Fig. 4. Basic Information Flow of SEVAC



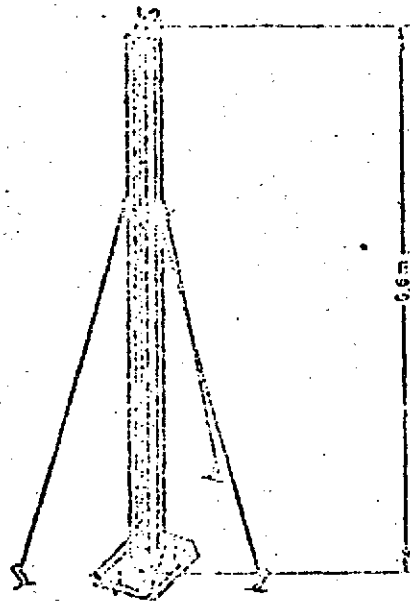
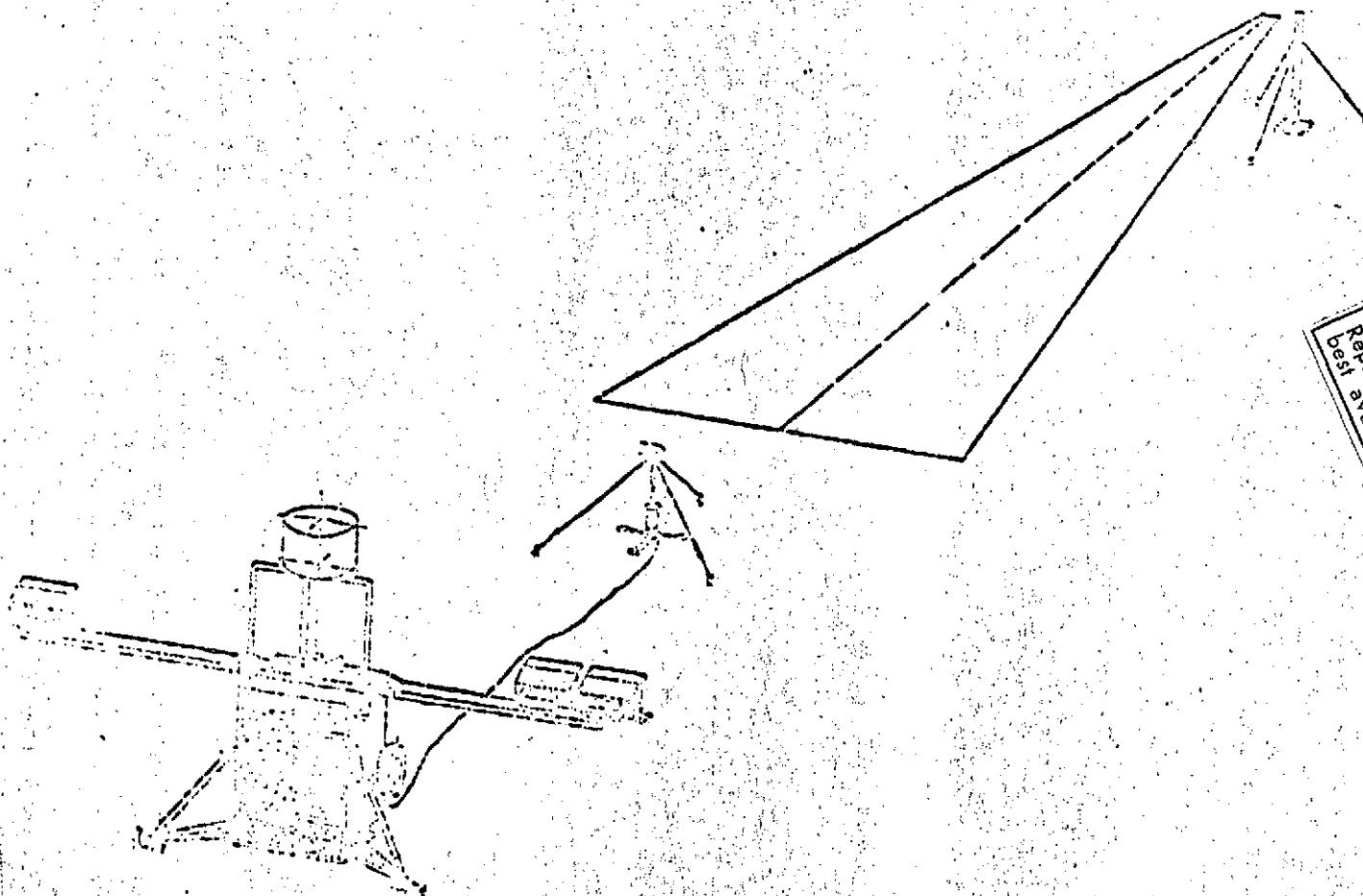


Fig. 13 SETC - E Groundstation operating



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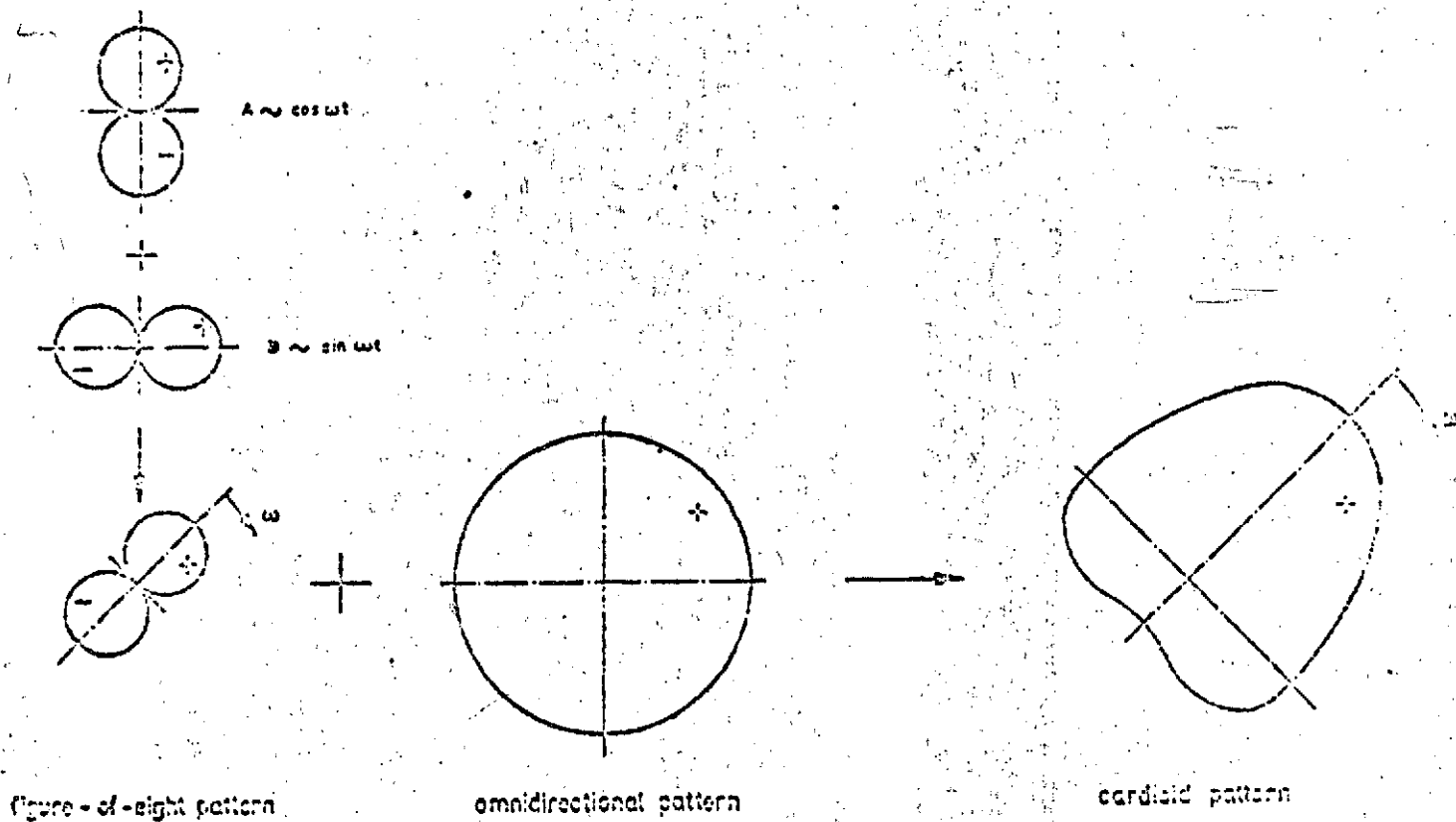


Fig. 7 Principles of operation of SROB

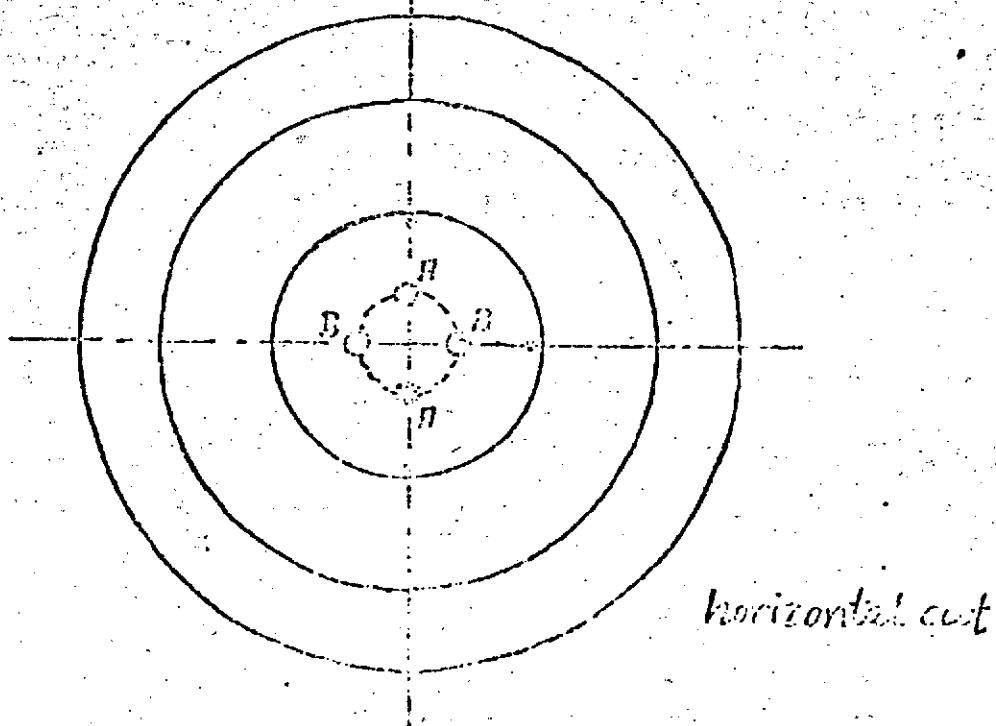
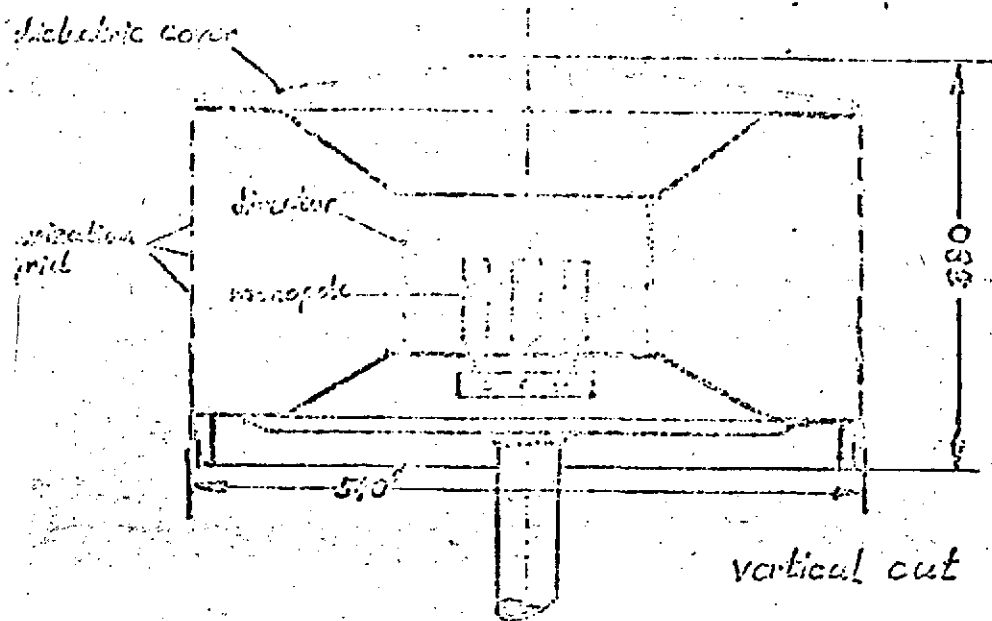


Fig. 2.2.4-4 Construction of the 5000 N.L. antenna

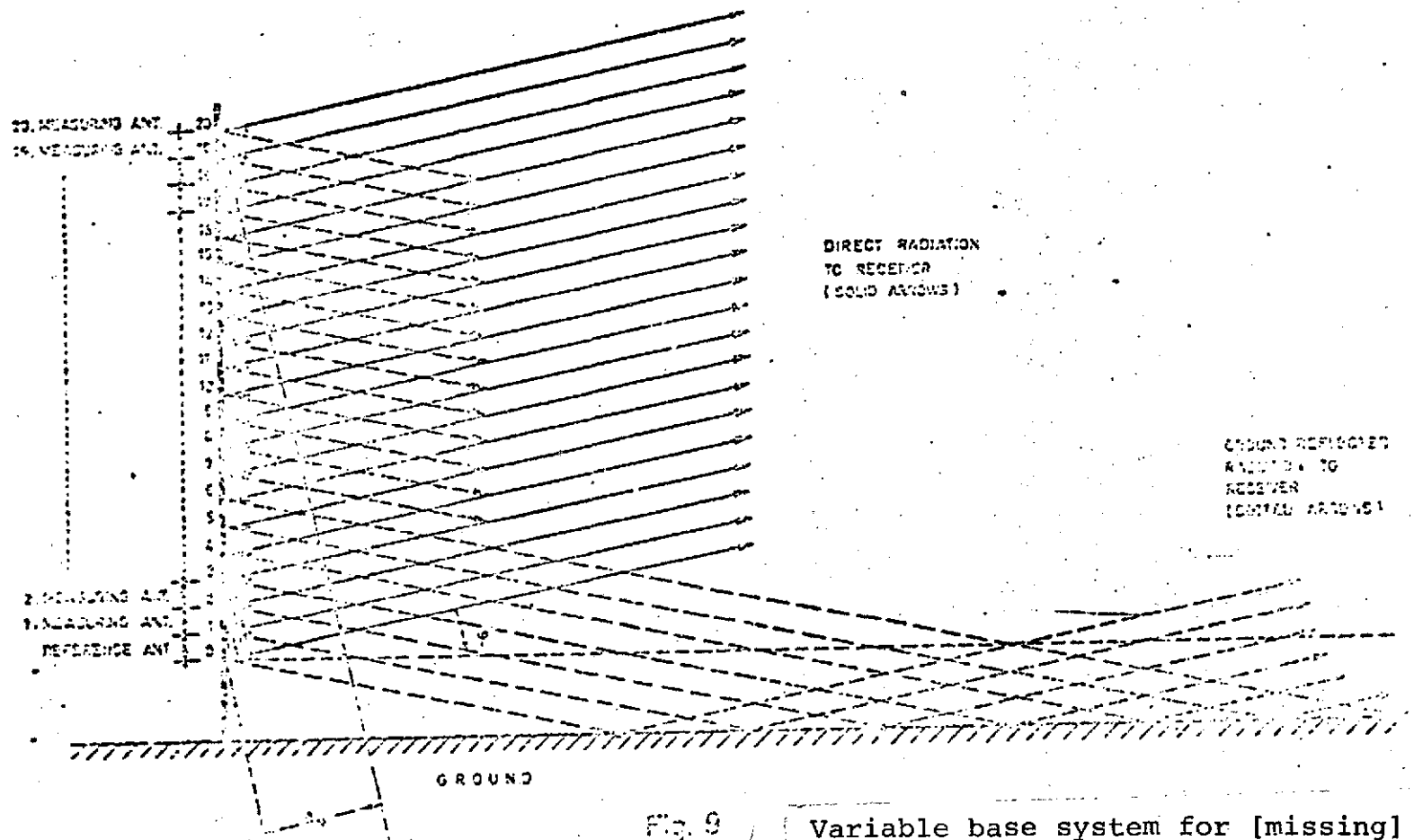
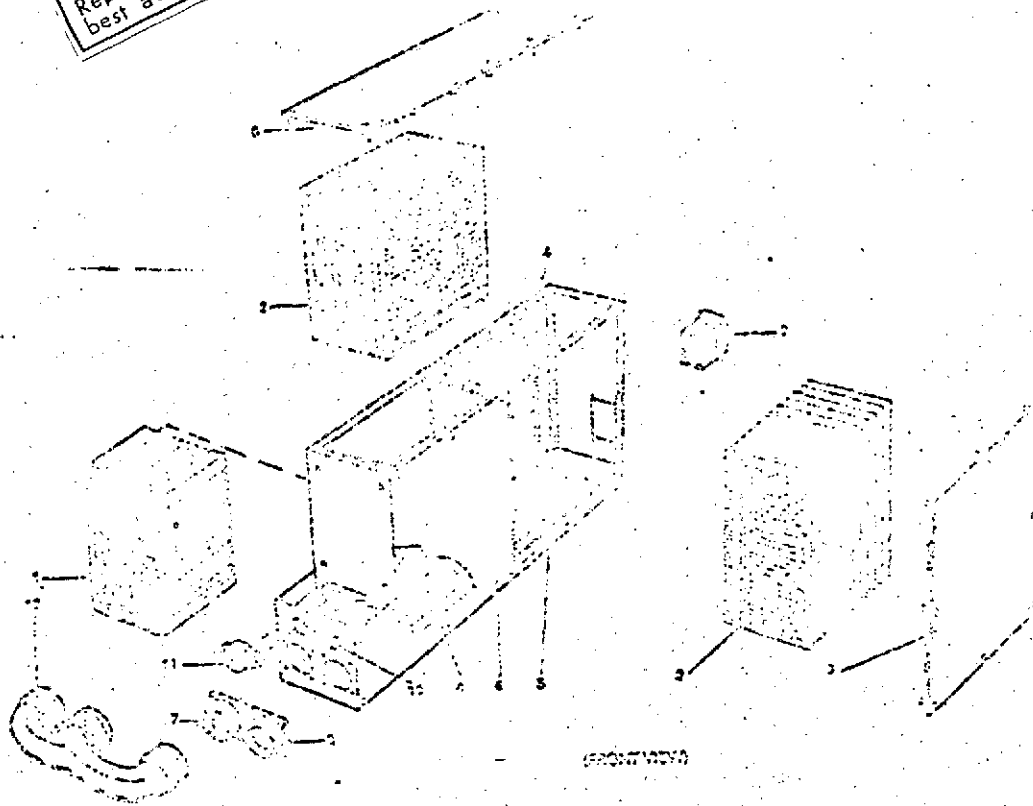


Fig. 9 Variable base system for [missing]

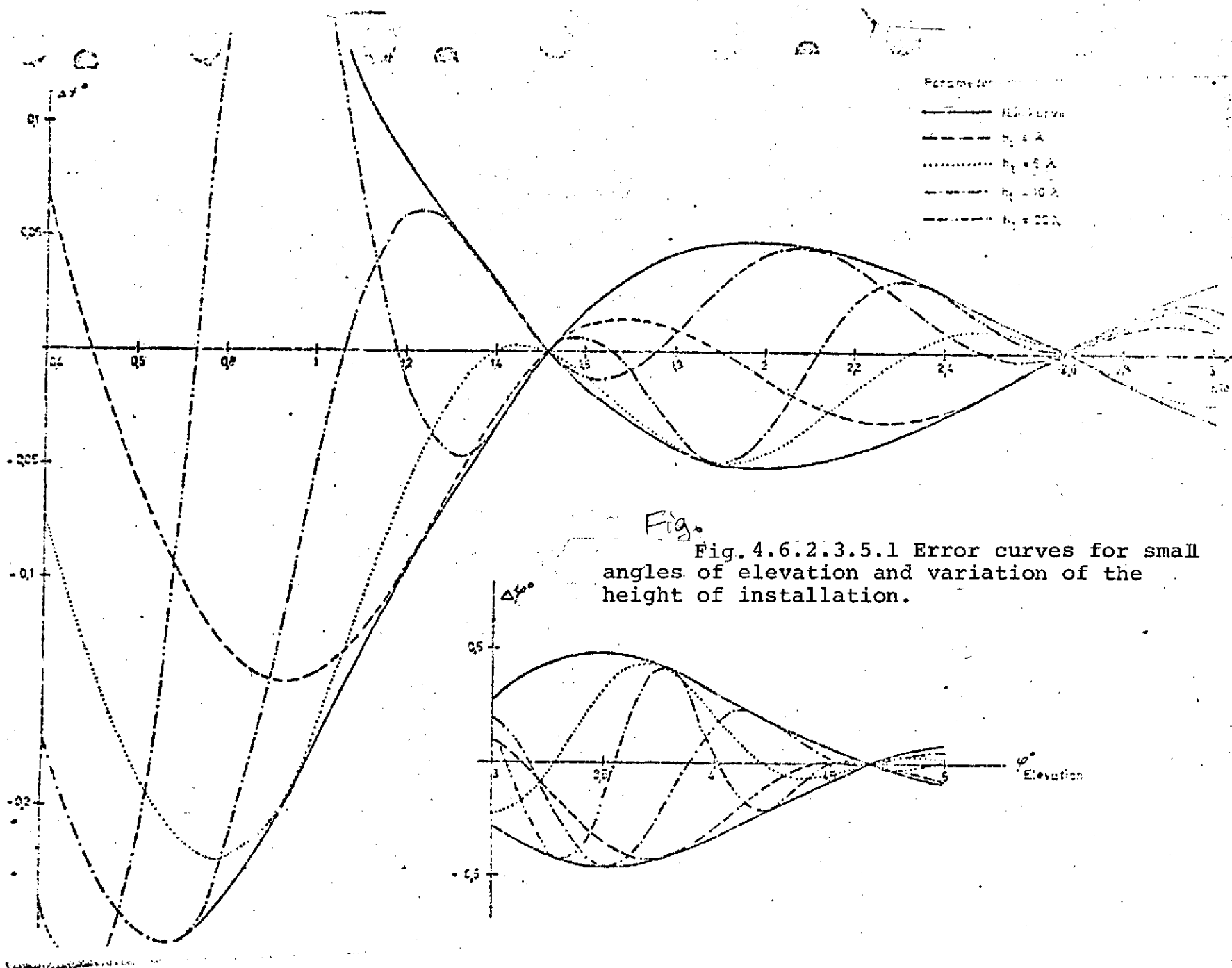
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COMPONENTS

1. 1/2" DIA. X 1/4" THK. ALUMINUM PLATE
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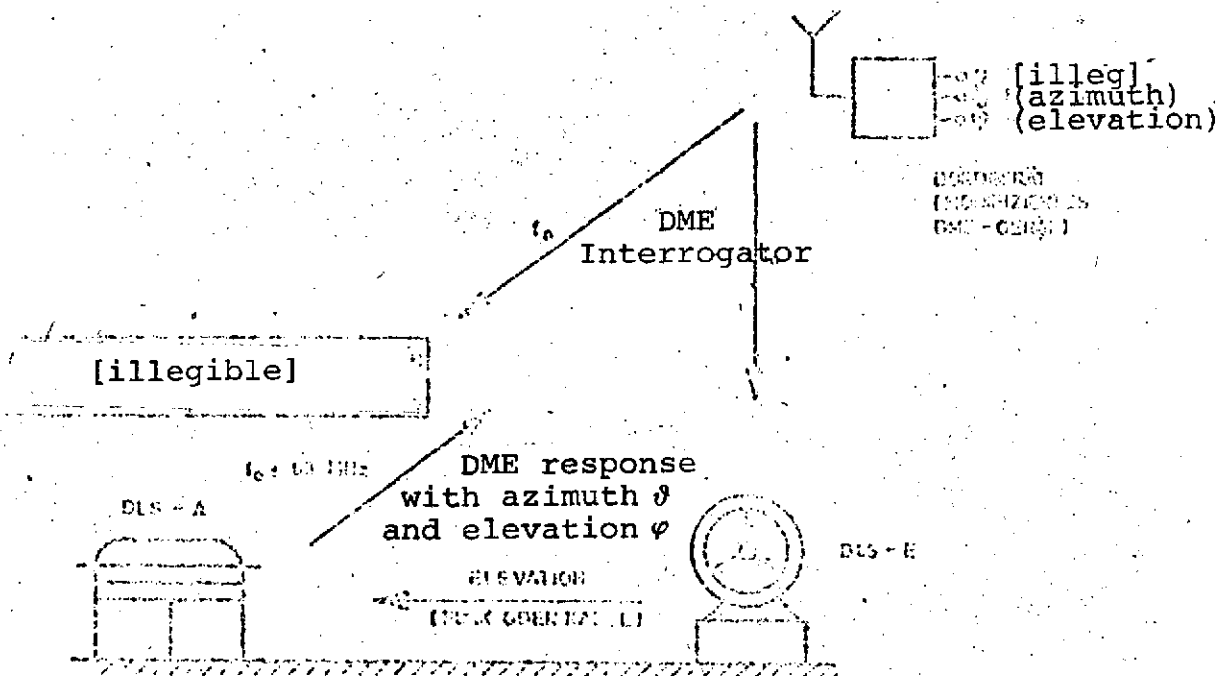
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10. 1/2" DIA. X 1/4" THK. ALUMINUM PLATE
11. 1/2" DIA. X 1/4" THK. ALUMINUM PLATE



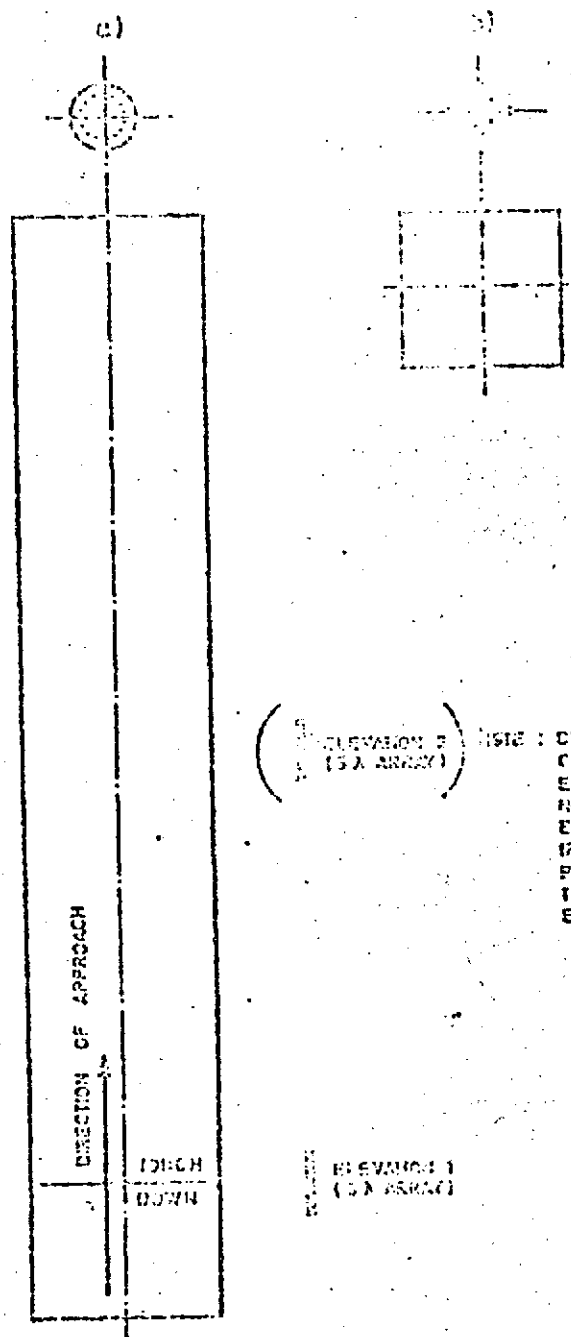
[illegible]

TABLE I

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Principal Information Flow on the DLS

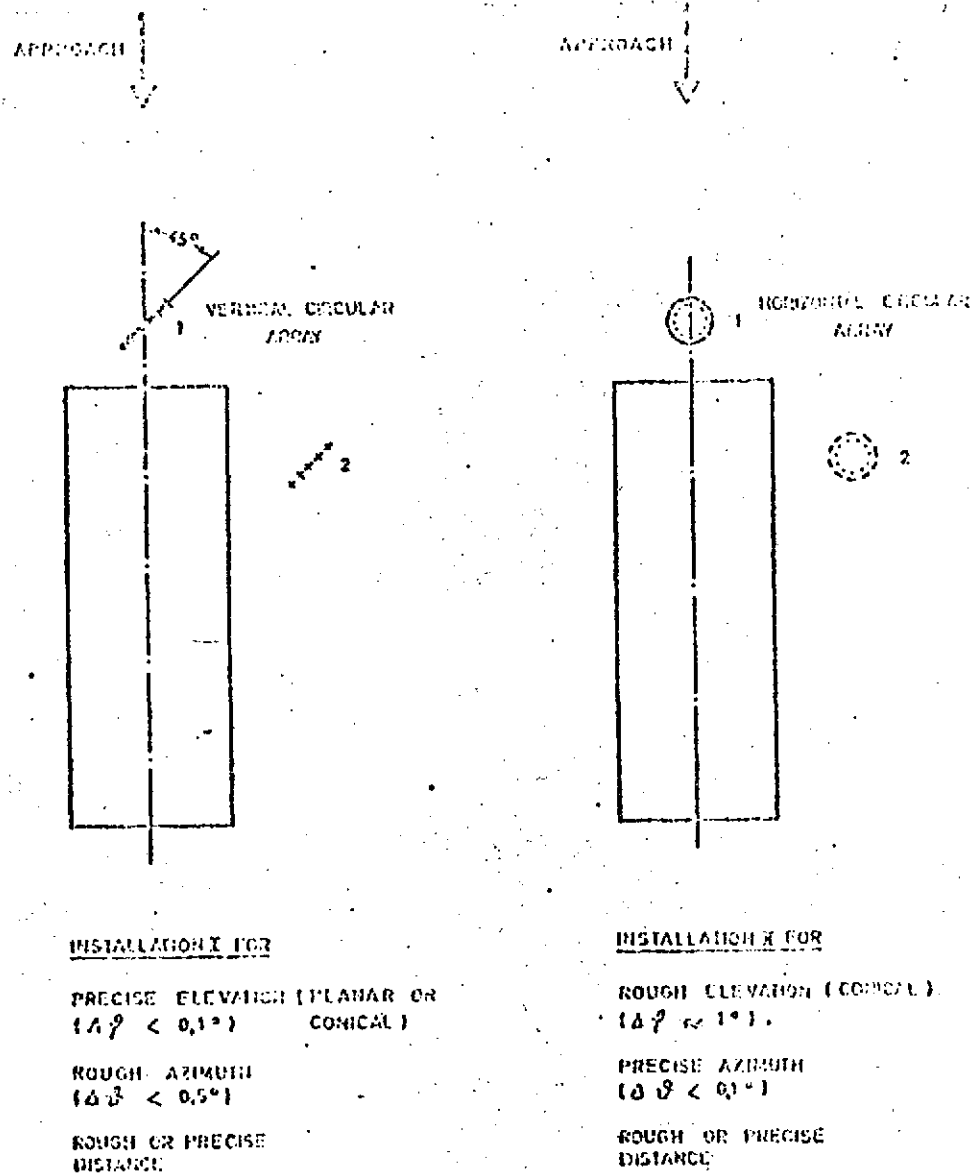


(ELEVATION 2 (SA ARRAY))

NOTE: DUE TO THE ACCURATE PLANNING COORDINATES OF THE 0-90° ELEVATION STATION THERE IS NO ARRANGEMENT USED FOR AN ELEVATION 2 SYSTEM. IF NECESSARY VLI, IT CAN BE PROVIDED, BEING OPERATED ON THE SAME CHANNEL AS ELEVATION 1.

ELEVATION 1 (SA ARRAY)

Fig. 21a Basic DIS configurations
a) CIOL and CIGL operations
b) VIOL operations



NOTE: IT IS ASSUMED THAT FOR SHORT GENERAL AVIATION AIRFIELDS FOR LOW-SPEED AIRCRAFT THE INSTALLATION CAN BE MADE IN FRONT OF THE RUNWAY (1) OR BESIDE THE TOUCH DOWN POINT (2)

Fig. 21 b DLS low cost ground installation for general aviation airfields or simplified military applications



U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22151

Date: September 18, 1974

Reply to:
Attn of: 954.01

Subject: NASA Document Discrepancy Report

74-120

To: Mr. E. E. Baker
Deputy General Manager
Informatics TISCO
P. O. Box 33
College Park, Maryland 20740

Re: N74-28100

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- ☒ 2. Portions of this document are illegible when reproduced. Please provide a reproducible copy. Marked by paper clips.
- ☐ 3. A microfiche reproduction is not legible. The case file was not received. Please provide at least an acceptable microfiche.
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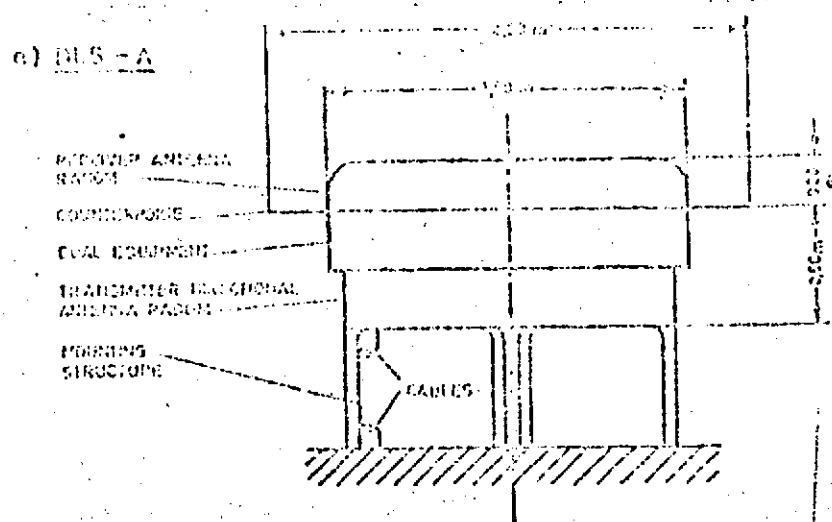
Lawrence J. Placencia

Phone: 703 -321-8517
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Response

Before	After
Issue Ch. of Status	
Code	Code
Comp. Ser.-No Act.	
Delay Ch. OF Status	
Post(ed) on Form 107	

PLEASE ATTACH COPY OF THIS LETTER WITH YOUR RESPONSE



b) DLS - E

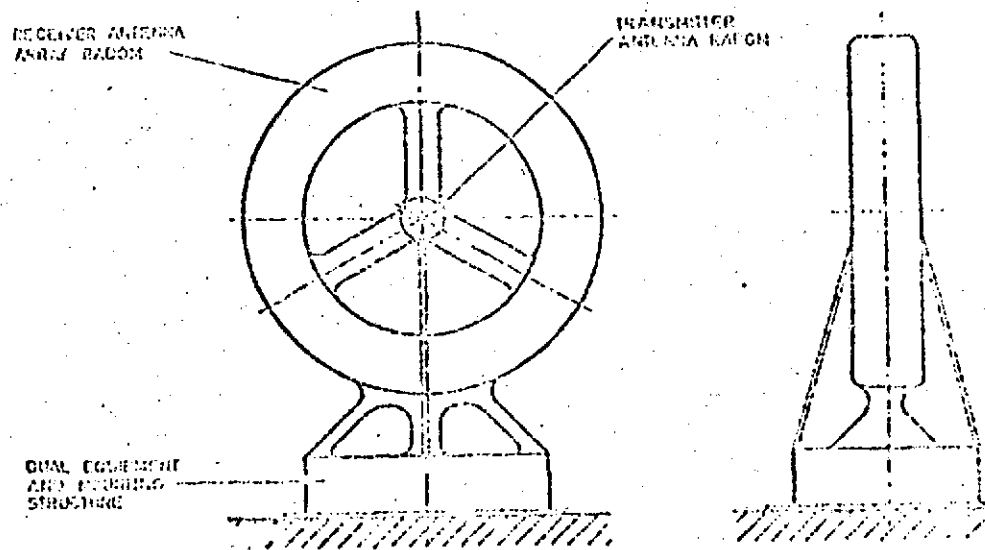


Fig. 22 Sketch of outside appearance of DLS azimuth and elevation stations (before final installation)